Chapter 4
Line-of-Protection and Minimum Facility Analysis Concepts

4-1. Overview

a. This chapter discusses the hydrologic engineering analysis for studies where the line-of-protection is analyzed as part of the study prior to analysis of the interior system. It focuses on hydrologic engineering study requirements and associated HEC-IFH analysis capabilities for implementing a minimum interior facility as part of a line-of-protection project.

b. The study strategy assumes that the interior facilities (which will become part of the recommended plan) are planned and evaluated separately and incrementally from the line-of-protection project. The major project (levee/floodwall) is conceptually divided from the planned interior facilities by initially evaluating a minimum facility considered integral to the line-of-protection. If a levee/floodwall exists, the minimum interior facility is that which is presently in place. If the levee/floodwall is being planned, the minimum facility must be formulated and the evaluation of the line-of-protection benefits performed with the facility in place. The residual interior flooding is the target of the interior planning efforts; benefits attributed to the increased interior facilities will be the reduction in the residual damage.

c. The following sections assume that the line-of-protection does not exist and is being planned as the initial part of the investigation. The minimum facility analysis is therefore part of the study.

4-2. Without Line-of-Protection Condition Analysis

a. Overview. The without line-of-protection condition assumes no protection is in place. HEC-IFH cannot directly analyze the without-project condition. Traditional analytical procedures and programs, beyond the scope of this document, are used. It is briefly discussed here because the hydrologic runoff analyses of the main stem (exterior) and local stream (interior) and their coincidence and dependence may be applicable in subsequent interior analyses involving HEC-IFH analysis.

b. Hydrologic engineering analysis concepts.

(1) The without line-of-protection analysis is often complicated by the coincident and dependent nature of flooding from the main stem and local stream. The nature of flooding between the main stem and local stream is critical to the type of hydrologic engineering approach used and the corresponding flood damage computations. Is the flooding between the two systems coincident? Are the events dependent? The assessment of the study area to determine the coincidence and dependence of flooding from the main stem and local stream is often a complex but necessary step in flood damage analyses. Section 2-3 and Table 2-1 describe coincidence and dependence for interior studies, and are relevant for line-of-protection feasibility studies. Figure 4-1 illustrates how a damage center can be flooded by both the main stem and the local stream runoff.

(2) The dependence of events causing the flooding of the two systems can influence the type of hydrologic analysis. Analysis of observed or historical events should always be used for validation and calibration of the assumptions and results. If the main stem and local stream are highly dependent, such as for a main stem drainage area that is relatively small (e.g., 259 sq km or 100 sq miles) in comparison to the local stream (e.g., 25.9 sq km or 10 sq miles), the same storm events would likely affect each system. Analyses would normally include evaluation of balanced hypothetical storms over both systems. For thunderstorms, the evaluation may also include storms centering over the interior area. Continuous record analysis could also be used, if sufficient data are available.

(3) For studies with no or little dependence, such as a 25.9-sq-km (10-sq-mile) local stream flowing into the Mississippi River main stem, a different approach is normally required. The events causing flooding are likely independent and may be highly noncoincident. Again, assessment of historic data and other information is required to assure this assumption is valid. Assuming it is, the two systems could be analyzed using the coincident frequency method or continuous record analyses described in Chapter 2.

(4) For most studies, the degree of dependence and coincidence will not be at the two extremes. The hydrologic engineering analysis may include continuous records, hypothetical event type studies, or combinations of both. As applicable, all other information and analyses should be used to provide data and insights as to the reasonableness of the results.

4-3. With Line-of-Protection and No Interior Facilities

a. General. The formulation and evaluation of the size and configuration of the line-of-protection are separate problems beyond the focus of this document. Required analysis procedures are described in the following documents:

- Guidance for Conducting Civil Works Planning Studies, ER 1105-2-100.

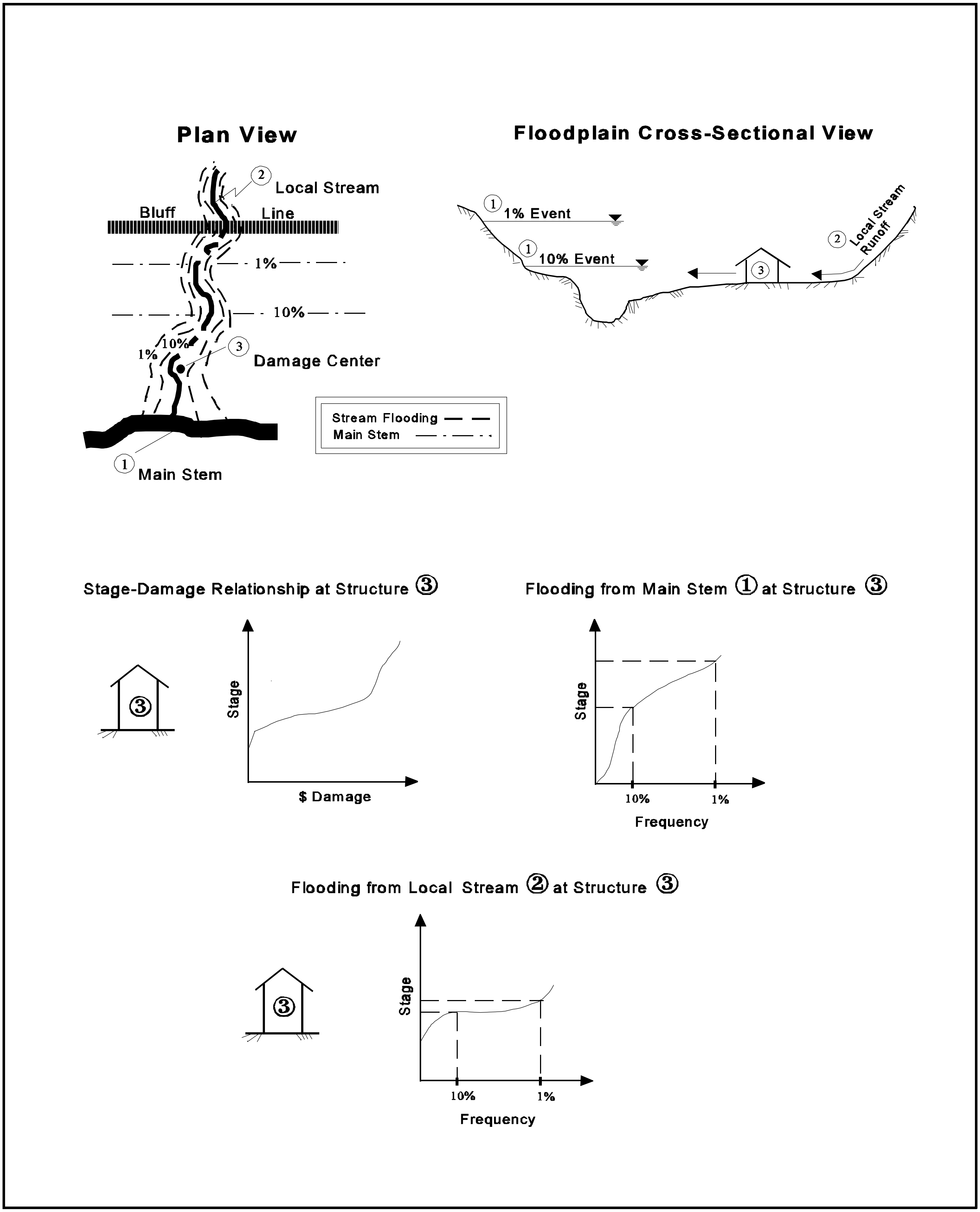

Figure 4-1. Without line-of-protection flooding

- Risk-Based Analysis for Evaluation of Hydrology/ Hydraulics and Economics in Flood Damage Reduction Studies, EC 1105-2-205.

- Hydrologic Analysis of Interior Areas, EM 1110-2-1413.

- Hydraulic Design for Local Flood Protection Projects, ER 1110-2-1405, and other documents.

For the interior area analysis, the line-of-protection is assumed in place and local stream conveyance to the main stem or exterior is cut off by the line-of-protection as shown in Figure 4-2. The runoff and contributing area of the existing and potential storm sewer system must be considered. Flooding from the exterior is blocked by the line-of-protection up to the overtopping event. This is the without-project condition for the minimum facility analysis and represents an upper bound for the stage-frequency relationship with the minimum facility in place. The goal is to subsequently reduce the stage-frequency relationship for the local stream without the line-of-protection in place by implementing the minimum facility discussed in the following section.

b. HEC-IFH analysis. HEC-IFH may be used to determine the stage-frequency relationship for the ponding area associated with the line-of-protection in place and no interior facilities. The runoff procedures and hydrographs generated for the local stream are often event-based since this condition only represents an upper limit for the minimum facility analysis and has no outlets to enable evacuation of water from the interior area. The analysis will normally be HEA but could be discrete observed events using HEC-IFH analysis that includes a plan consisting of the PRECIP, RUNOFF, POND, EXSTAGE, and perhaps AUXFLOW modules. Gravity outlets and pumps are not analyzed. Stage-frequency relationships may be developed for each interior ponding area using HEC-IFH. The local stream runoff analysis may be the same as described for the without line-of-protection condition including, if applicable, future without-project conditions. The difference, however, is that local stream runoff will pond behind the line-of-protection and main stem (exterior) flooding will be blocked to the top of the line-of-protection.

4-4. Minimum Facility Analysis

a. General. The minimum facility of the interior area is justified as an integral part of the line-of-protection as shown in Figure 4-3. The minimum facility should provide interior flood protection during gravity (unblocked or low exterior) conditions such that the local storm sewer system functions essentially the same as it did without a levee in place for floods up to the storm sewer design. The stage-frequency relationship for the with-minimum-facility-in-place condition becomes the without-project condition for evaluating additional interior flood damage reduction measures. The residual damage with the minimum facility in place is thus the target for damage reduction of additional flood reduction measures.

b. Storm sewer design and configuration.

(1) The layout, planned changes, design discharges, and invert elevations of existing and potential future storm sewer systems must be considered as part of the minimum facility analysis. These data are used to define contributing drainage areas, invert elevations of major conveyance channels, gravity outlet inverts, pump on-off elevations, and local design criteria for inlet and outlet works. Data collection and analysis of storm sewer systems, which include the existing and future system layout, design, and operation information, are generally provided by the local public works department or city engineer. The proper delineation of drainage areas that contribute to the interior ponding adjacent to the line-of-protection is important to the interior analysis. The natural topography should be used for initial boundaries. The storm sewer layout often crosses topographic boundaries and thus may affect the amount of runoff into or out of the system.

(2) The location of flow concentration at the line-of-protection often affects where gravity outlets or pumps may be located and the layout of the collector/conveyance system adjacent to the line-of-protection. The potential of combining flows into a collector system should be evaluated. Finally, if a storm sewer system does not exist, one may need to be designed to assure the interior system is compatible with contributing flow areas and invert elevations of any planned interior flood damage reduction system.

(3) The effect of storm sewers may be analyzed using HEC-IFH by modifying the unit hydrograph for events affected by storm sewers in the RUNOFF module of HEC-IFH. The contributing drainage areas may also be adjusted in the RUNOFF module or the AUXFLOW diversion option can be used to adjust storm sewer flows into or out of the subbasin. The time series of runoff hydrographs, including storm sewer flows, may be imported into HEC-IFH (AUXFLOW module) instead of directly calculating the runoff. This is appropriate for complex systems and those requiring more sophisticated runoff computations such as for situations when pressure storm sewer flows are a significant issue.

c. Evaluate range of minimum facilities. The minimum facility will almost always consist of gravity outlets, but may include pumps if the coincidence of flooding between the interior and exterior is high for very prolonged periods such as for lakes or new upstream storage projects. The physical characteristics of the minimum facility gravity outlets should be established prior to the analysis and refined as the analysis proceeds. The analysis should be performed for the range of hypothetical frequency events. The analysis is performed

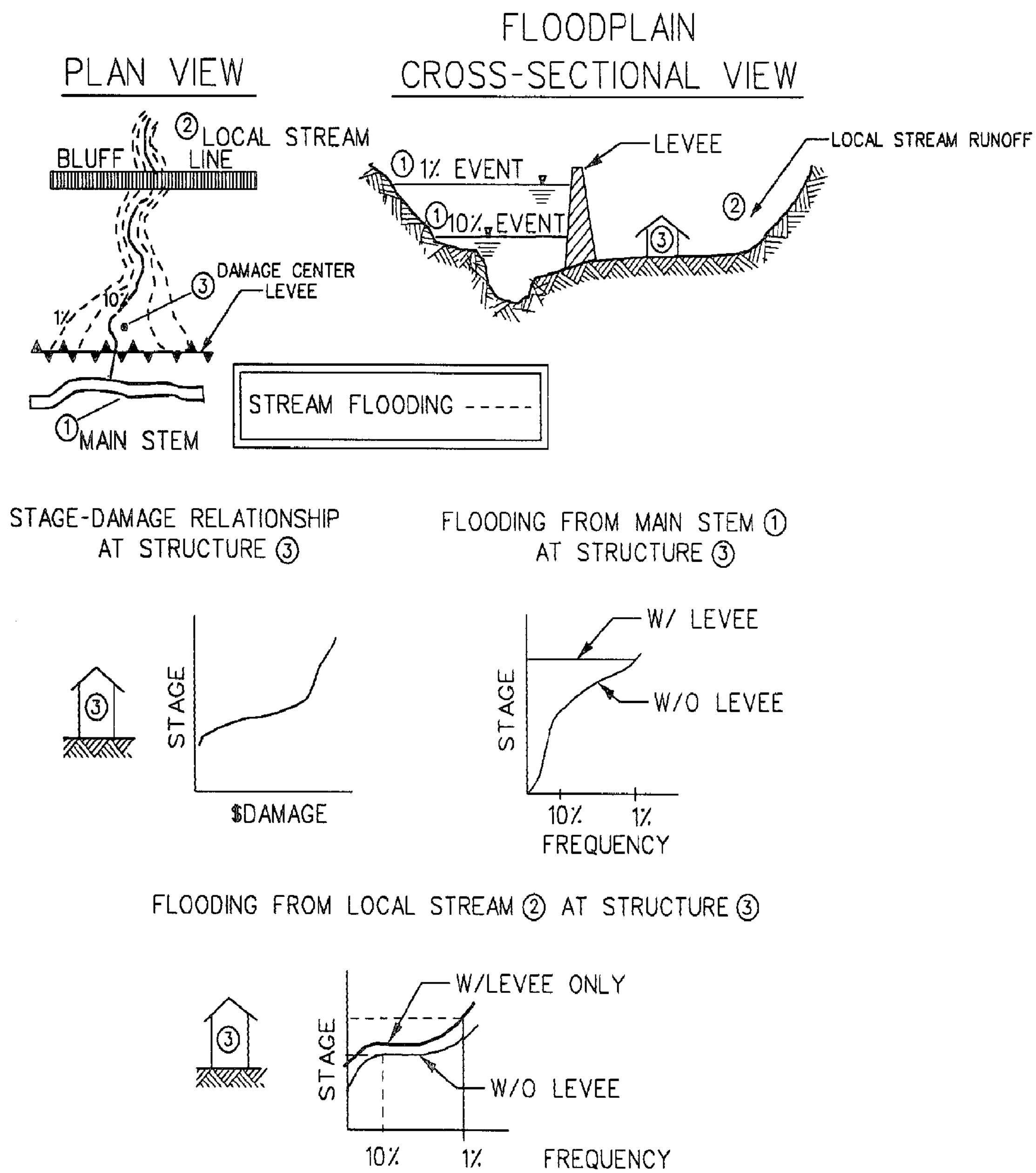

Figure 4-2. Line-of-protection without minimum facility

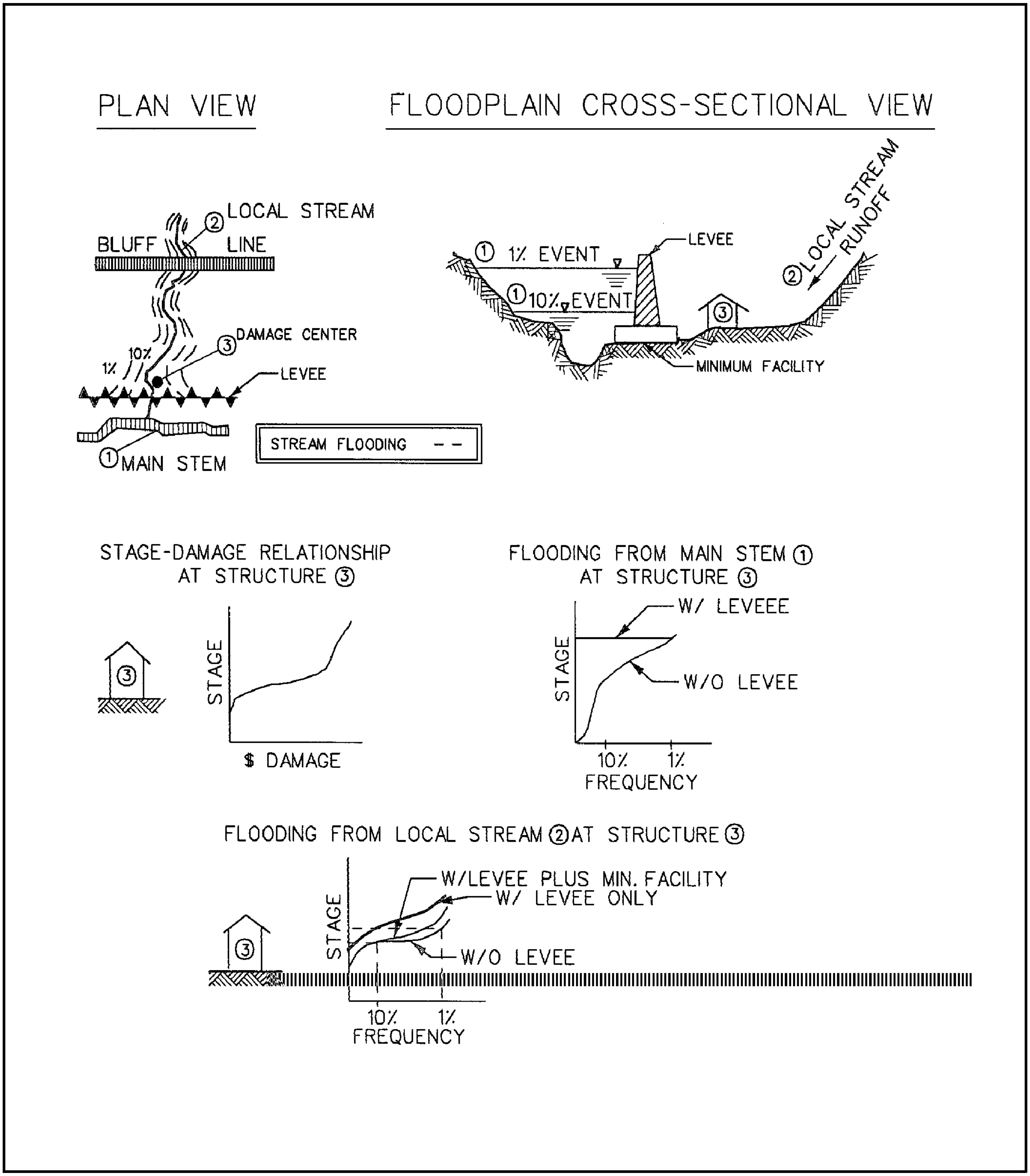

Figure 4-3. Line-of-protection with minimum facility

assuming unblocked gravity outlet conditions. Each plan evaluated would include the same data or PRECIP, RUNOFF, POND, EXSTAGE, and AUXFLOW modules as the without line-of-protection condition plus the GRAVITY module.

d. Minimum facility sizing analyses. The following paragraphs describe the strategy for sizing the minimum gravity outlet facility using HEC-IFH.

(1) Define three or four gravity outlet configurations (different GRAVITY modules) of increasing capacity. Outlet sizes should envelop the largest storm sewer size or ditch capacity at the line-of-protection.

(2) Enter the gravity outlet data requirements into HEC-IFH. Both the CSA and HEA methods have the same data requirements. For interior analyses, the outlet headwater is the interior ponding elevation and the tailwater is the exterior stage. The following two items of information are required for each gravity outlet:

(a) A gravity outlet rating table that lists the headwater depth required for a range of outlet flow rates and tailwater depths. This table may be entered by the user or computed by HEC-IFH for circular or box culverts. Generally, the user will choose the option that allows the program to compute the outlet rating tables.

(b) HEC-IFH allows the user to adjust the exterior stage or tailwater condition to match the actual location of each gravity outlet.

(3) Define a new plan for each gravity outlet capacity to be evaluated. All HEC-IFH data entry modules will be the same except the GRAVITY module will change for each plan. Using local storm HEA, compare the results of each plan using the program's plan comparison capability. The plan comparison assessment should be for the with line-of-protection and no outlets (Section 4-3) condition and each gravity outlet plan analyzed by HEC-IFH. They should then be compared to the targeted local stream frequency that is not computed in HEC-IFH.

(4) Select the minimum facility which is the gravity outlet capacity or plan that essentially makes the stage-frequency and associated flood damage to the interior area no worse than flooding to the area from the local stream without the line-of-protection in place. Rarer events, which exceed the local storm sewer design, may be greater with the minimum facility in place. See Figure 4-3.

4-5. Summary

The minimum facility is justified as part of the line-of-protection. It is almost always gravity outlets. Minimum facility analysis involves both the base year conditions and at least one future condition analysis, if it is likely to change and impact the analysis. Interior stage-frequency relationships for these conditions may be needed to select a minimum facility. The minimum facility provides interior flood protection during unblocked or low exterior conditions such that the local storm sewer system functions essentially the same as without the levee in place for floods up to the storm system design. The subsequent without-project condition is used to formulate and evaluate interior flood damage reduction measures assuming the minimum facility in place.